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The association between the early motor repertoire and language development in term children born after normal pregnancy

Sahar Salavati[1,2], **Christa Einspieler**[2], **Giulia Vagelli**[3,4], **Dajie Zhang**[2], **Jasmin Pansy**[5], **Johannes G M Burgerhof**[6], **Peter B Marschik**[2,7], and **Arend F Bos**[1]

[1]Division of Neonatology, Department of Pediatrics, Beatrix Children's Hospital, University Medical Center Groningen, University of Groningen, Groningen, Netherlands [2]Research Unit iDN - interdisciplinary Developmental Neuroscience, Institute of Physiology, Center for Physiological Medicine, Medical University of Graz, Graz, Austria [3]SMILE Lab, Department of Developmental Neuroscience, Stella Maris Scientific Institute, Pisa, Italy [4]Department of Clinical and Experimental Medicine, University of Pisa, Italy [5]Division of Neonatology, Department of Pediatrics and Adolescent Medicine, Medical University of Graz, Graz, Austria [6]Department of Epidemiology, University of Groningen, University Medical Center Groningen, Groningen, the Netherlands [7]Center of Neurodevelopmental Disorders (KIND), Department of Women's and Children's Health, Karolinska Institutet, Stockholm, Sweden

Abstract

Background—The assessment of the early motor repertoire is a widely used method for assessing the infant's neurological status.

Aim—To determine the association between the early motor repertoire and language development.

Study design—Prospective cohort study.

Subjects—22 term children born after normal pregnancy; video recorded for the assessment of the early motor repertoire including their motor optimality score (MOS), according to Prechtl, at 3 and 5 months post term.

Outcome measures—At 4 years 7 months and 10 years 5 months, we tested the children's language performance by administering three tests for expressive language and two for receptive language.

Results—Smooth and fluent movements at 3 months of age was associated with better expressive language outcome at both 4 years 7 months and 10 years 5 months (betas 0.363 and 0.628). A higher MOS at 5 months was associated with better expressive language at both ages (betas 0.486 and 0.628). The item postural patterns at 5 months was the only aspect associated with poorer expressive language outcome (beta -0.677).

Corresponding author: Sahar Salavati, Hanzeplein 1, 9713 Groningen, The Netherlands, (s.salavati@umcg.nl). Fax: +3150 361 4235.

Conflicts of interest

The authors have stated that they had no interests that might be perceived as posing conflict or bias.

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Conclusion—Predominantly, qualitative aspects of the early motor repertoire at the age of 3 and 5 months are associated with language development.

Keywords

Early motor repertoire; General movements; Language development; Expressive language; Receptive language; Healthy term-born children

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1 Introduction

The General Movement Assessment (GMA) and assessment of the early motor repertoire are reliable tools for assessing the infant's neurological status.(1, 2) Previous research has demonstrated the predictive value of different aspects of the early motor repertoire in relation to minor neurological dysfunctions (MND) in preterm-born children and in children with inborn errors of metabolism,(3–5) in relation to intelligence at school age in preterm-born children,(5, 6) and in relation to the level of self-mobility in children with cerebral palsy.(7–9) Hitzert et al. reported that even in typically developing children detailed aspects of the early motor repertoire were associated with cognition and behaviour at school age.(1, 10)

General movements are endogenously generated, complex movement patterns and they are part of the infant's spontaneous motor repertoire. Fidgety movements (FMs) are the type of general movements specific for the age 6 to 9 up to 15 to 20 weeks post term. They are described as small and subtle movements and can be judged as either normal, abnormal or absent. FMs co-exist with other movements and postural patterns.(2) Together this comprises the infant's early motor repertoire, which can be assessed by using the motor optimality score (MOS).

Most of the research performed on the predictive value of the early motor repertoire focused on developmental domains other than language. Language development is not always optimal, not even in typically developing children.(11) This implies that variation in language development exists in children who are otherwise expected to develop normally. Before studying language development in high-risk infants, however, it should first be assessed in low-risk children in order to identify developmental trends.(12) Because several aspects of the early motor repertoire prove to be associated with cognition and motor skills later in life,(3, 4, 6–9) we focused on the early motor repertoire to explore its association with language development.

The aim of this exploratory study was to determine the association between several aspects of the early motor repertoire and language development in a cohort of full-term children.

2 Material and methods

2.1 Participants

After obtaining informed consent, we recruited 62 children at the Department of Obstetrics and Gynaecology, Medical University of Graz, Austria, to investigate various developmental processes including language development. We followed the children prospectively and

longitudinally from birth to childhood. The cohort was videoed at 3 and 5 months to assess their early motor repertoire. At 4 years 7 months and 10 years 5 months we contacted the cohort for participation in follow-up of several developmental domains among which language tests. Retrospectively, we included 22 children (nine boys and 13 girls) of whom results of language tests and at least one video recording was available. They were all born within the same 3-week interval in 1998. The inclusion criteria were: singleton, born at term (38-41 weeks), birth weight appropriate-for-gestational-age, residing in or close to Graz and belonging to a monolingual, Austrian-German speaking family. During the follow-up age-appropriate neurological examinations were performed, the latest at 4 years 7 months. Minor neurological dysfunction (MND) was diagnosed at that time according to the neurological examination based on Touwen.(13) The study was part of FWF Project P16984 and was approved by the institutional review board of the Medical University of Graz, Austria.

2.2 Video recording and assessment of early motor repertoire

Video recordings of between 2 to 5 minutes were made at 3 months (median 13 weeks, range 10-15) and 5 months (median 20 weeks, range 17-22). During the recording the infants were in active wakefulness (between feedings) and were partly dressed, lying in supine position.

Two certified scorers (G.V. and S.S.), who were not familiar with the children's clinical and developmental history, assessed the video recordings according to the Prechtl GMA as normal or abnormal FMs.(2) In case of disagreement between the scorers, the segment of the recording concerned was re-assessed together with a third scorer, C.E., a licensed GMA trainer. In all cases the final score was decided by consensus.

Next, S.S. determined the infant's motor optimality score (MOS).(14) Any doubts were discussed with C.E. Previously, the inter-scorer agreement for MOS has been reported as good, with Cohen's Kappa statistics varying from 0.75 to 0.91.(15) The MOS comprises five subscales which we scored according to the manual: FMs (normal 12 points, abnormal 4 points, absent 1 point), repertoire of co-existent other movements (optimal 4 points, reduced repertoire 2 points, absent repertoire 1 point), quality of other movements (normal > abnormal 4 points, normal = abnormal 2 points, normal < abnormal 1 point), postural patterns (normal > abnormal 4 points, normal = abnormal 2 points, normal < abnormal 1 point) and movement character (smooth and fluent 4 points, abnormal but not cramped-synchronized 2 points, cramped-synchronized 1 point).(5, 14) We did, however, make one exception: if an infant did not show FMs at 5 months but instead displayed advanced motor development such as antigravity movements and/or rolling onto its side, the physiological absence of FMs scored 12 points, i.e. normal. All children were term born after a normal pregnancy and hence we expected no severe abnormalities in their early motor repertoires. The best possible performance was scored 28 points and the worst possible performance scored 5 points. If only one of the subscales, apart from FMs, showed reduced optimality we considered the MOS to be near-optimal. If two or more subscales showed reduced optimality we considered the MOS to be non-optimal. In this way we dichotomized the children according to the MOS in two groups: 25 to 28 near-optimal to optimal and 24 and below as non-optimal.(5)

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2.3 Language assessments in childhood

At the age of 4 years 7 months, we administered various tests on vocabulary composition and complexity. Firstly, we administered the Aktiver Wortschatztest - Revision (AWST-R), a picture-naming test. The sum of the pictures that are correctly described corresponds to the extent of the child's expressive vocabulary.(16) Secondly, we used the Noun-Verb Test (NVT), which is comparable to the AWST-R. In this case the participants had to describe what they saw on different pictures. It tests expressive vocabulary for both nouns and verbs; a higher number of correctly described pictures is reflected by a higher score.(17) Thirdly, we administered the third edition of the Peabody Picture Vocabulary Test (PPVT-III) to assess receptive single-word vocabulary in response to pictorial stimuli. Each pictorial stimulus is called an item and all the items are grouped into blocks of four.(18)

At the age of 10 years 5 months, we tested the children's expressive verbal abilities with the *Wortschatz* [vocabulary] subscale of the fourth edition of the Hamburg-Wechsler-Intelligenztest für Kinder (HAWIK), the German-language version of the Wechsler Intelligence Scale for Children (WISC).(19) We tested receptive language with the Test for Reception of Grammar (TROG) - Deutsch [German] and analysed the results both quantitatively and qualitatively. The TROG examines children's comprehension of the grammatical structures of the German language that are marked, for example, by inflection, functional words and word order.(20)

An overview of the psychometric properties and way of scoring of all language tests is given in Table 1. The duration of each test varied from 10 to 20 minutes with a pause between tests. Assessment continued until the stopping rules had been met.

2.4 Statistical analysis

For two subscales of the early motor repertoire we made an adjustment before analysing the data. Firstly, because all children showed more normal than abnormal on quality of other movements, we refrained from statistical analyses on this subscale. Secondly, we divided the item postural patterns into two categories, N>A and N≤A, instead of the original three, since N=A and N<A are both suboptimal scores.

We performed the statistical analysis by using SPSS Statistics for Mac, Version 22 (SPSS Inc., Chicago, IL). To evaluate the associations between the aspects of the early motor repertoire and the language tests, we performed univariable linear regression analyses and present the data as standardized regression coefficients (beta), including the 95% confidence interval of beta. Next, we performed multivariable linear regression analyses, including all variables with $p<0.25$ in the univariable analyses, to find the best explanatory model for each language test based on aspects of the early motor repertoire. We adjusted the analyses for gestational age and socio-economic status of the mother, defined by university, college or secondary education. In the multivariable analyses, for those variables that remained in the model, we present the regression coefficient B with 95% confidence interval of B, the standardized regression coefficient beta, the explained variance r squared, and the p-value. For all multivariable analyses, we considered $p<0.05$ (two-tailed) as statistically significant.

3 Results

3.1 Participants

The mean gestational age was 39.9 ± 0.8 weeks (mean ± SD). Birth weight was 3486 ± 387 grams. Regarding the socio-economic status of the mothers, five had completed university, 11 college and six secondary education. Video recordings of three infants were not available at 3 months and of another four infants at 5 months. Two children were diagnosed with MND.

3.2 Motor repertoire in infancy

The scores for the subscales of the MOS at 3 and 5 months are presented in Table 2. The median MOS was 26 points at 3 months and 24 points at 5 months. At 3 months, 10 infants obtained optimal scores and the scores of nine infants were non-optimal. At 5 months, nine infants had optimal and nine infants had non-optimal scores. FMs at 3 months were absent in two out of 19 infants. At 5 months, one of these infants had normal FMs and they were absent in the other infant. At follow-up, these two children were consistently diagnosed with MND.

3.3 Language performance in childhood

An overview of the language scores at 4 years 7 months and 10 years 5 months is given in Table 3. The children's scores were within the normal range.

3.4 Univariable associations between the early motor repertoire and language development in childhood

We present all univariable associations between the early motor repertoire and language tests in Table 4. In particular, a smooth and fluent movement character at 3 months was associated with better language performance. Additionally, a higher MOS and the presence of normal FMs were associated with better language performance. For the MOS we found more associations when using the metric scale than when MOS was dichotomised into an optimal and non-optimal category. Of note, the MOS and FMs were associated with certain language tests and not others, whereas the movement character was associated with all language tests.

At 5 months, a higher MOS was associated with better language performance. Similar to our finding at 3 months, a smooth and fluent movement character and the presence of normal FMs were associated with better language performance. Nevertheless, the number of significant associations were fewer at 5 months than at 3 months.

All significant associations indicate that higher MOSs and their subscales were related to better language outcomes with one exception: higher scores at 5 months on the postural patterns subscale were related to poorer results on the HAWIK subscale.

3.5 Multivariable associations between the early motor repertoire in infancy and language development in childhood

The outcomes of multivariable analyses are presented in Table 5. The MOS, postural patterns and movement character remained significantly associated with language outcome.

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We observed that of the language tests, the HAWIK subscale was most often significantly associated with aspects of the early motor repertoire.

The strongest association we found was between the MOS (metric scale) and postural patterns at 5 months. Together they explained 68.8% of the variance of the performance on the HAWIK subscale.

4 Discussion

This study demonstrates that several aspects of the early motor repertoire at 3 to 5 months of term infants born after normal pregnancy are associated with language performance during childhood. Univariable analyses showed that this applied to both the development of expressive and receptive language skills. The aspects we found to be associated consisted nearly exclusively of qualitative characteristics of the early motor repertoire. Firstly, a better MOS was associated with higher scores on expressive and receptive language tests at both 4 years 7 months and 10 years 5 months. Secondly, the presence of normal FMs at both 3 and 5 months was associated with better expressive and receptive language scores at 10 years 5 months. Thirdly, a smooth and fluent movement character was associated with better language performance on most of the tests. Fourthly, we found no associations between the repertoire and quality of other co-existent movement patterns, and language. For postural patterns we found only one association where higher scores on the postural patterns subscale were associated with poorer scores on the HAWIK subscale. Finally, associations remained strong in multivariable models for expressive language tests.

We found that the MOS, which is an overall measure of the quality of the early motor repertoire, was associated with children's performance on various language tests. Better scores on the MOS, obtained at 5 months, were associated with better scores on expressive language. The metric MOS was more sensitive for predicting language performance than dichotomising MOS into an optimal or non-optimal category. Our findings are in line with those of Butcher et al., who reported on the usefulness of the MOS as a predictor of later intelligence in preterm-born children.(6)

When focusing on the different subscales of the MOS, we found that movement character was most often associated with language performance. This qualitative measure showed its relevance particularly when assessed at the age of 3 months. At this age associations were found with all language tests except the PPVT-III sets. The movement character at 5 months was also associated with both expressive and receptive language, but only with the language tests we administered at 4 years 7 months. Previously, several other studies have reported on the significance of movement character for later development. Many studies reported on the association with motor development in both high-risk infants (1, 4, 7) and in typically developing infants.(10, 21) Movement character was also reported to predict cognitive outcome later on.(1, 10, 22) We now add that qualitative characteristics of the early motor repertoire also predict language development of term children born after normal pregnancy.

Another qualitative measure of the early motor repertoire we found to be important for language development was FMs. Even in our small sample of 19 infants, in which 17

showed normal FMs and two did not, we found that the absence of FMs was associated with poorer expressive and receptive language skills at 10 years 5 months. The absence of FMs at 5 months, including the absence of an age-appropriate concurrent repertoire, showed the same association with expressive language at 10 years 5 months. Previously, FMs have not been studied in relation to language development. It is well known that the absence of FMs is highly predictive of later major motor disorders.(2) The few times FMs were studied in relation to cognitive outcome, results were conflicting. Butcher et al. reported that in preterm-born children, FMs were not related to intelligence at school age,(6) while Spittle et al. reported that the absence of FMs predicted moderate to severe impairment of general cognitive ability at toddler and preschool age.(23)

The only association we found on the subscales of the MOS that involved a quantitative measure was the postural patterns subscale. A higher score on this subscale at 5 months was associated with poorer scores on the HAWIK subscale, an expressive language test, at 10 years 5 months. Strikingly, this association occurred in the opposite direction than we expected. This may be a chance finding, because we found no associations between the postural patterns subscale at 3 months and language development. Butcher et al. reported that in preterm-born children a higher score on postural patterns was associated with higher intelligence later on.(6) This finding was based on both the number of normal and abnormal postural patterns. Additionally, Einspieler et al. reported that ‘several qualitative, and quantitative aspects of the concurrent motor repertoire, including postural patterns, were predictive of intelligence at 7-10 years of age.’(9) We approached the variable slightly differently than in the studies above, in the sense that we dichotomised this variable and that we did not perform statistics on the number of postural patterns.

We advance possible explanations for our findings. We found significant associations with the early motor repertoire, particularly for the expressive language tests AWST-R and HAWIK subscale, the first being tested at 4 years 7 months and the latter at 10 years 5 months of age. Leonard et al. showed that in infants who are at increased risk of developing autism spectrum disorder, early motor delay impacts the rate of development of expressive language.(24) From these findings we hypothesise that an optimal early motor repertoire is a precondition for the development of expressive language. More studies are required to elucidate this.

Another more general explanation involves parent-child interaction. A previous study showed that the quality of infants’ early motor repertoire might explain some of the variability in the interactions between preterm-born infants and their mothers.(25) It might be that smooth and fluent movements on the part of the infant lead to another type of parent-child interaction than non-fluent movements. It is known that language development already starts early on in life. Together this may explain our findings regarding the association with language performance later on, although vocalisation of the mother played no role in the study to which we referred.24 This explanation is of course highly speculative.

We recognise several limitations to our study. We investigated many possible associations due to the number of aspects of the early motor repertoire and the language tests. We did not adjust for multiple comparisons as our study was exploratory in the sense of generating

hypotheses regarding possible associations between the early motor repertoire and language development. We acknowledge the risk of greater false positives in this study. Even so, we were surprised to find so many positive associations between movement quality of the early motor repertoire and language performance in such a small group. Furthermore, we were surprised that FMs were absent in two infants. In their study on 74 typically developing childen Hitzert et al. reported that FMs were not found absent in any of the participants.(10) In the present study, however, the two infants in whom FMs were absent, were consistently diagnosed with MND at follow-up, indicating non-optimal brain functioning. This is also reflected in the association we found between FMs and language performance.

A strength of our study is that it was longitudinal and the first to describe the associations between the early motor repertoire and language development in children born after normal pregnancy.

This explorative study brings us closer to unravelling the associations between the early motor repertoire and language development. The associations we found open up possibilities to identify, in various groups of infants, those infants at risk of developing language problems. We know that problems in developmental domains are more likely to occur in for instance preterm-born infants,(4, 22) more so than in typically developing infants. This study confirms that even in term children born after normal pregnancy the ranges in language development are broad.(26) Our results could therefore be helpful in identifying children at risk of language problems.

5 Conclusions

Our study demonstrates associations between the early motor repertoire at 3 to 5 months and expressive rather than receptive language performance in childhood. Nearly exclusively, qualitative characteristics of movement character are the strongest predictor of language performance. The associations we found in term children born after normal pregnancy should be investigated in children at risk of developmental problems.

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Abbreviations

AWST-R	Aktiver Wortschatztest – Revision
FMs	fidgety movements
GMA	general movements assessment
HAWIK	Hamburg-Wechsler-Intelligenztest für Kinder
MND	minor neurological dysfunction
MOS	motor optimality score
NVT	Noun-Verb Test

PPVT-III	Peabody Picture Vocabulary Test third edition
TROG	Test for Reception of Grammar
WISC	Wechsler Intelligence Scale for Children

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Table 1

Psychometric properties and way of scoring of the language tests

Language test	Validity	Reliability	Items tested	Scored as
AWST-R(16)	Established	alpha 0.88	75	Number of correct responses
Noun-Verb test (17)	Established	”good”		Number of correct responses
- *Nouns*			36	
- *Verbs*			36	
- *Composite*			72	
PPVT-III (18)	Established	alpha 0.92-0.98		Number of items correctly responded to; number of sets filled in with at least 5 out of 12 items correct, according to the test-manual
- *Items*			204	
- *Sets*			17	
HAWIK (subscale Wortschatz) (19)	Established	”good”	36	Number of correct responses
TROG (20)	Established	alpha 0.86		Number of correct responses
- *Items*			84	
- *Blocks*			21	

Key: AWST-R, Aktiver Wortschatztest - Revision; PPVT-III, Peabody Picture Vocabulary Test, third edition; HAWIK, Hamburg-Wechsler-Intelligenztest für Kinder, fourth edition; TROG, Test for Reception of Grammar – Deutsch

Table 2

Assessment of the early motor repertoire

MOS	Score	n=22
Early motor repertoire at 3 months		n=19
Fidgety movements	Present	17
	Absent	2
Repertoire of co-existent other movements	Age-adequate	13
	Reduced	6
Quality of other movements	Normal > abnormal	19
Postural patterns	Normal > abnormal	13
	Normal = abnormal	2
	Normal < abnormal	4
Movement character	Smooth and fluent	7
	Monotonous, jerky	12
Early motor repertoire at 5 months		n=18
Fidgety movements *	Present	10
	Absent	8
Repertoire of co-existent other movements	Age-adequate	5
	Reduced	13
Quality of other movements	Normal > abnormal	18
Postural patterns	Normal > abnormal	12
	Normal = abnormal	3
	Normal < abnormal	2
Movement character	Smooth and fluent	10
	Monotonous, jerky	8

* The absence of fidgety movements at 5 months may still be considered normal, because the obligatory age for fidgety movements may have passed.

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Table 3

Scores on the language tests of the children

Test/scale name	Domain	Part used	Median (P_{25}; P_{75})	Age (years; months)
AWST-R	Expressive vocabulary	Total raw score (nouns, verbs and adjectives)	65 (58; 73.5)	4;7
NVT	Expressive vocabulary	Nouns (N)	33 (31.00; 34.00)	4;7
		Verbs (V)	25.00 (22.50; 28.00)	
		Composite (N + V)	59.00 (53.75; 62.00)	
PPVT-III	Receptive vocabulary	Items correct	65 (55; 83)	4;7
		Sets correct	7 (5; 9)	
HAWIK	Expressive vocabulary	*Wortschatz*	13.00 (11.5; 15.00)	10;5
TROG	Receptive vocabulary; Grammar	Items correct	80 (78; 83)	10;5
		Blocks correct	19 (17; 20)	

Key: AWST-R, Aktiver Wortschatztest - Revision; NVT, Noun-Verb Test; PPVT, Peabody Picture Vocabulary Test, third edition; HAWIK, Hamburg-Wechsler-Intelligenztest für Kinder, fourth edition; TROG, Test for Reception of Grammar - Deutsch

Table 4

Associations between early motor repertoire and language with p<0.250 using univariable analyses represented by betas with 95%-confidence intervals unadjusted for confounders

Early motor repertoire / Language test	MOS (points)	MOS (dich)	FMs	RC	P[&]	MC
Early motor repertoire at 3 months						
AWST-R						0.300# (-0.188; 0.788)
NVT nouns						0.279# (-0.212; 0.771)
NVT verbs		0.351# (-0.128; 0.830)				0.382# (-0.090; 0.855)
NVT composite						0.391± (-0.080; 0.862)
PPVT-III items						0.299# (-0.189; 0.787)
PPVT-III sets						
HAWIK subscale	0.341# (-0.157; 0.839)		0.323# (-0.179; 0.824)			0.628* (0.216; 1.041)
TROG items	0.318# (-0.184; 0.821)		0.409± (-0.074; 0.893)			0.337# (-0.162; 0.893)
TROG blocks			0.295# (-0.211; 0.802)			0.295# (-0.211; 0.802)
Early motor repertoire at 5 months						
AWST-R	0.537* (0.072; 1.001)					0.382# (-0.126; 0.891)
NVT nouns						
NVT verbs						
NVT composite						
PPVT-III items	0.362# (-0.132; 0.856)	0.401± (-0.084; 0.887)				0.406± (-0.078; 0.891)
PPVT-III sets	0.327# (-0.132; 0.856)	0.382# (-0.107; 0.872)				0.350# (-0.147; 0.846)
HAWIK subscale	0.497* (0.037; 0.957)		0.319# (-0.183; 0.821)		-0.555* (-0.996; -0.114)	
TROG items	0.356# (-0.139; 0.851)					
TROG blocks						

Key: # stands for $p<0.250$; ± stands for $p<0.100$; * stands for $p<0.05$; [&] we dichotomized this variable for the analyses leading to a group of N > A postural patterns and a group of N =A and N < A; MOS (points), Motor Optimality Score in points; MOS (dich), Motor Optimality Score dichotomised; FMs, fidgety movements; RC, repertoire of co-existent other movements; P, postural patterns; MC, movement character; AWST-R, Aktiver Wortschatztest - Revision; NVT, Noun-Verb Test; PPVT-III, Peabody Picture Vocabulary Test, third edition; HAWIK, Hamburg-Wechsler-Intelligenztest für Kinder, fourth edition; TROG, Test for Reception of Grammar - Deutsch

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Table 5

Significant associations between early motor repertoire and language using multivariable regression analyses adjusted for sex, gestational age and socio-economic status

Language test	Predictors	B (95 % CI)	beta	R^2	*p* model
Early motor repertoire at 3 months					
AWST-R *1	MC	6.1 (-1.05; 13.367)	0.363	0.358	0.029
NVT composite *1	MC	4.5 (-0.908; 9.812)	0.391	0.153	0.098 *5
HAWIK subscale *2	MC	3.1 (1.061; 5.106)	0.628	0.395	0.005
TROG items *2	MC	3.5 (-0.539; 7.572)	0.406	0.294	0.074 *5
Early motor repertoire at 5 months					
AWST-R *3	MOS (points)	1.0 (0.164; 1.830)	0.486	0.504	0.007
PPVT-III items *3	MC	20.0 (-3.772; 43.172)	0.406	0.165	0.094 *5
HAWIK subscale *4	MOS (points) P	0.3 (0.164; 0.490) -3.5 (-5.076; -1.862)	0.628 -0.677	0.688	0.000

Key: CI, confidence interval; MC, movement character; FMs, fidgety movements; MOS (points), Motor Optimality Score in points; P, postural patterns; AWST-R, Aktiver Wortschatztest - Revision; NVT, Noun-Verb Test; PPVT, Peabody Picture Vocabulary Test, third edition; HAWIK, Hamburg-Wechsler-Intelligenztest für Kinder, fourth edition; TROG, Test for Reception of Grammar - Deutsch

*1 MC was included in the model

*2 MOS (points), FMs and MC were included in the model

*3 MOS (points) and MC were included in the model

*4 MOS (points), FMs, postural patterns were included in the model

*5 $0.05 \leq p < 0.1$, predictor remained in the model